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# THE PLAGIOCLASE FELDSPARS AS A CASE OF ATOMIC ISOMORPHISM

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The peculiar composition of the plagioclase feldspars was first rationally explained by Tschermak,[1] and his view that they represent solid solutions of two end-members, albite and anorthite, has gained general acceptance. The crystallographic, physical, and fusion phenomena show that the solid solution is of isomorphous character.

The empirical formulas of the plagioclase end-members are $NaAlSi_3O_8$ and $CaAl_2Si_2O_8$ respectively. Because these two formulas are of apparently dissimilar chemical type, there have been numerous attempts to account for this instance of isomorphism. These fall more or less definitely into three groups: (1) The structural formula viewpoint, which assumes that the elements retain the same valence in the solid that they have in the liquid form, and that isomorphism of metals is always valence for valence, but that widely dissimilar acid radicles may be isomorphous; (2) the arithmetical viewpoint, which finds in simple integral relationships between constituents or their properties sufficient explanation for isomorphism; and (3) the atomic isomorphism viewpoint, which admits isomorphism only between mutually similar atoms or groups, the valence of which, however, is not required to be the same in the solid as in the liquid form of the elements concerned.

The more important contributions to each of these viewpoints will here be reviewed, and it will be pointed out that a simplified form of (3) is in the light of our present knowledge the only reasonable interpretation of the isomorphism of the plagioclases.

[1] *Ber. Akad. Wiss. Wien,* **50**, 566, 1865.

No explanation of the isomorphism in question can be accepted if it does not account for the molecular volume relations, the practical non-replaceability of aluminium by iron, and the very limited isomorphism of orthoclase ($KAlSi_3O_8$) and carnegieite ($Na_2Al_2Si_2O_8$) with anorthite.

That the "molecular volumes" of empirical-formula amounts of albite and anorthite are identical has been recognized for so long that it is not certain who first pointed it out. The term molecular volume is somewhat of a misnomer, for it refers not to the volume of a single molecule, but to that of an amount of the substance measured by the formula weight in grams; "gram-formula volume" is therefore preferable. This is obtained by dividing the formula weight by the density. In the present instance the formula weights are not accurately known, for the atomic weight of aluminium may be anywhere between 26.95 and 27.10, that of silicon between 28.10 and 28.30; moreover, few workers agree on the densities beyond the first decimal place. Using average values, $NaAlSi_3O_8$ amounts to 262.7, and as the density of pure albite is 2.60, the g-f.v. is 101 cc.; $CaAl_2Si_2O_8$ amounts to 278.6 and the density of anorthite is 2.76, so its g-f.v. is the same as that of the preceding. As shown more particularly by Prior,[2] a similar relation holds in many cases of isomorphism between substances of apparently distinct formula type. Of course, identity of g-f.v. is not sufficient to explain a case of isomorphism, but it does point to the conclusion that the isomorphism in the plagioclases is based on a 1:1 ratio of empirical formula amounts of the two end-numbers, and that no explanation of it should be accepted which assumes any other ratio between them.

The non-replaceability of aluminium by iron in the feldspars is striking. Such ferric feldspars as have been made artificially are unstable, and in nature when any ferric oxide gets incorporated with a feldspar at the time of its crystallization it separates as inclusions of hematite. The gem orthoclase of Madagascar may be an exception to this rule, but it is nearly, if not quite, unique. On the other hand, in certain other silicates, as for instance garnet, epidote, and tourmaline, ferric iron appears to be able to replace aluminium readily and extensively. The well known instability of the ferrates as compared with the aluminates suggests that these relations are due to the fact that in the feldspars the aluminium is not basic as in garnet, etc., but belongs to the acid radicle, a view emphasized by Vernadsky[3] but not given the consideration it deserves by later writers.

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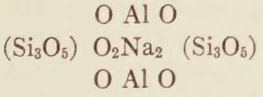
[2] *Mineralogical Mag.*, 13, 217, 1903.

Since the only difference between orthoclase and albite appears to consist in the replacement of one univalent metal by another, it would be expected that orthoclase would likewise be isomorphous with anorthite. Alling[4] suggested that this is the case, and named the series oranite, but he gave no data to show that such solid solutions of orthoclase and anorthite as may conceivably occur in nature are really of isomorphous character. The grouping of the hundreds of analyses he plotted seems on the contrary to indicate definitely that only limited, non-isomorphous solid solution exists.

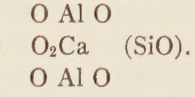
It might also be expected that carnegieite would be isomorphous with anorthite, since the chief difference between them consists in the replacement of two univalent sodium atoms for one bivalent calcium atom. That this is, however, not the case is shown by the extreme rarity and at best small carnegieite content of the feldspar anemousite, as well as by the careful synthetic experiments of Bowen,[5] whose determination that carnegieite holds only 5 per cent of anorthite and anorthite only 2 per cent of nephelite-carnegieite clearly indicates that these solid solutions are non-isomorphous.

(1) Structural formula interpretations.—In the paper of Vernadsky cited, the feldspars were regarded as underlain by a "mica nucleus," and from the description of this conception it would appear that he looked upon albite as something like



$$\begin{matrix} & \text{O Al O} & \\ (Si_3O_5) & O_2Na_2 & (Si_3O_5) \\ & \text{O Al O} & \end{matrix}$$

and anorthite as



$$\begin{matrix} & \text{O Al O} & \\ (SiO) & O_2Ca & (SiO). \\ & \text{O Al O} & \end{matrix}$$

Except for the aluminium being part of the acid radicles in both, the two formulas are quite different.

The structural formulas of Clarke[6] differ from the preceding ones in regarding aluminium as basic and not connected with the alkali or alkaline earth metals, albite being $Na\text{-}O\text{-}Si \equiv O_3 \equiv Si - O - Si \equiv O_3 \equiv Al$ and anorthite $Al \equiv O_3 \equiv Si - O - Ca - O - Si \equiv O_3 \equiv Al$.

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[3] *Z. Kryst. Min.*, **34**, 60-61, 1901.

[4] *J. Geol.*, **29**, 193, 1921.

[5] *Am. J. Sci.*, **33**, 571, 1912.

[6] *U. S. Geol. Survey Bulls.* **125** and **588**.

He definitely accepted the two markedly dissimilar silicate radicles, $(Si_3O_8)$ and $(SiO_4)$, as mutually equivalent. This viewpoint is popular among American mineralogists, being, in spite of the considerable volume of literature on the subject herein cited, often the only one mentioned in discussions of the relationships between silicates, as for instance in the monograph on the feldspars by Alling. Clarke and others have used the assumed equivalence between these two silicate radicles to account for the excess silica in nephelite, micas, zeolites, etc. But in nephelite, at least, it has been clearly shown by Bowen[7] that the solid solution is limited and, therefore, presumably non-isomorphous; and the other instances can be equally well explained on various assumptions.

The structural formula viewpoint would appear to have reached its climax in the monstrous ring formulas of the Asches,[8] which may be passed over without further consideration.

As an anti-climax, Gossner[9] has written formulas for these minerals according to a pseudo-coördination plan, albite becoming $SiO_3Na_2\ (SiO_2Al_2O_3).4SiO_2$ and anorthite $SiO_3Ca\ (SiO_2AlO_3)$. He regarded these as very similar in type, but failed to note that the $4SiO_2$ is here isomorphous with nothing at all.

All of the plans of this group have the same failings. In the interest of having one bivalent calcium correspond to two univalent sodiums, they are willing to consider quite dissimilar acid radicles isomorphously replaceable, and to disregard entirely the gram-formula volume relations by making two albites equivalent to one anorthite. Except in so far as Vernadsky recognized the close connection between aluminium and the alkali or alkaline earth metals, they assign no reasons for the lack of replaceability between iron and aluminium, potassium and sodium, and one calcium for two sodiums in carnegieite. Such structural formulas are, therefore, quite inacceptable.

(2) ARITHMETICAL INTERPRETATIONS.—The valence-volume theory of Pope and Barlow[10] appears to represent essentially a generalization from the chance relation that tetravalent carbon sometimes occupies approximately four times the volume of

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[7] *Am. J. Sci.*, **33**, 49, 1912; **43**, 115, 1917.

[8] The silicates in chemistry and commerce, 1913.

[9] *Centr. Min. Geol.*, **1921**, 522.

[10] *J. Chem. Soc.*, **89**, 1675, 1906.

univalent hydrogen. It is quite unsupported by gram-formula volume data in general, and merits little attention. The total valence of both albite and anorthite is 32, as pointed out by these authors (p. 1727), but other silicates also have total valences of 32 and yet are not isomorphous with them.

The molecular compound viewpoint has been summed up clearly by Sosman.[11] According to it the oxides making up ordinary silicates (the feldspars were not mentioned specifically) tend to unite in simple numerical proportions regardless of structural formula relations, the resulting products being in a modern sense molecular compounds. On this basis albite would be $Na_2O.Al_2O_3.6SiO_2$, and anorthite $CaO.Al_2O_3.2SiO_2$, disagreeing with the gram-formula volumes in that albite is here doubled.

The isosterism viewpoint is an outgrowth of the octet theory of Langmuir.[12] Elements or radicles possessing like electron arrangement are regarded as capable of isomorphous equivalence even tho they are chemically apparently dissimilar. The available electrons in both albite and anorthite amount to 64, so as far as the whole formula amounts go, the two are alike. On the other hand, when the individual constituents are considered, it is found that calcium is isosteric with potassium but not with sodium, which would indicate anorthite to be more fully isomorphous with orthoclase than with albite, whereas actually the reverse is the case.

The chief objection to the viewpoints of this group consists in their failure to furnish any adequate explanation of the complexity of isomorphous relationships. If carried to their logical extreme, they would predict numerous cases of isomorphism which do not occur, practically requiring that the plagioclases should welcome replacement of one univalent, one bivalent, or one trivalent metal by any other with the corresponding valence, as lithium or potassium for sodium, strontium or barium for calcium, or ferric iron or chromium for aluminium; yet not one of these takes place. Arithmetical relations should be regarded as corollaries to, and not causes of, isomorphism.

(3) ATOMIC ISOMORPHISM INTERPRETATIONS.—By atomic isomorphism, as opposed to valence isomorphism, is meant the replacement of a single atom by one of another kind, irrespective of

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[11] *J. Ind. Eng. Chem.*, 8, 985, 1916.

[12] *J. Am. Chem. Soc.*, 41, 1557, 1919.

the valence exhibited by the same atoms in solution. This may be illustrated by the case of calcite and soda-niter, $CaCO_3$ and $NaNO_3$, which are so closely isomorphous that they form parallel overgrowths, whereas $CaCO_3$ and $Na_2CO_3$ are not isomorphous at all, and neither are $Ca(NO_3)_2$ and 2 $NaNO_3$. The structural formulas on the solution-valence basis would predict, on the other hand, that $Ca=O_2=C=O$ should be isomorphous with $Na_2=O_2=C=O$, but not with the structurally distinct $Na-O-N\equiv O_2$, and so on. It is of course possible to get around this by writing calcite as $(CaC)^{vi}\,O_3$, but this device does not really tell anything about the structure, although it does indicate double atomic isomorphism.

A viewpoint of this sort has actually been applied to the plagioclases, as mentioned by Groth,[13] and greatly extended by Washington.[14] Thereby albite becomes $(NaSi)^{v}\,(AlSi_2O_8)$ and anorthite $(CaAl)^{v}\,(AlSi_2O_8)$. This plan has the advantages of avoiding any necessity of assuming isomorphism between widely dissimilar acid radicles, and of corresponding to the gram-formula volume relations; but it does not account for the lack of replaceability of one atom by another of the same valence, and it implies splitting up of the atomic grouping in a manner for which there is no evidence.

One of the simplest methods of bringing out atomic isomorphism is the coördination plan of Werner,[15] which consists essentially of placing in brackets the dominant element of a compound together with such accessory elements or radicles as are firmly bound, and outside of the brackets more loosely bound ones. This plan has been applied to the plagioclases by Niggli[16] and Jakob,[17] although they unfortunately complicated matters by writing at least four different formulas of anorthite, ranging from $[SiO_6.SiO_2]^{Al_2}_{Ca}$ to $[Al(SiO_4SiO_2AlO_2)_3]^{Al_2}_{Ca_3}$, while albite became $[Al(SiO_4SiO_2SiO_2)_3]^{Al_2}_{Na_3}$. Niggli discovered, no doubt by patient research, that these formulations showed atomic isomorphism between Ca and Na and

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[13] Introduction to chemical crystallography, 1906, p. 85.

[14] *Am. J. Sci.*, 34, 555, 1912.

[15] New ideas on inorganic chemistry, 1911.

[16] Lehrbuch der Mineralogie, p. 379, 1920.

[17] *Z. Kryst. Min.*, 56, 299, 1921.

Al and Si. As, however, the relations between the constituents could be obscured equally well by various other modes of formulation on the coördination plan, it seems desirable to limit the choice of arrangements in some way.

DEVELOPMENT OF A SATISFACTORY INTERPRETATION.—From this review of the various explanations and their significance it is evident that any atomic isomorphism theory will account for the gram-formula volume relations of the plagioclases. The non-replaceability of aluminium by iron would seem to require, however, that the aluminium be definitely associated with the alkali or alkaline earth metal. The coördination plan is adapted to show this, an aluminium atom being regarded as dominant and given the central position, altho it is difficult to decide in the case of the feldspars which constituents are to be regarded as loosely bound and left outside the brackets. The extreme insolubility of albite, at least, suggests that all the constituents are so firmly bound as to deserve a place inside, giving $[Na\ Al\ (Si_3O_8)]$, but there would seem to be no need of retaining the brackets at all. Albite then becomes simply Na**Al** $(Si_3O_8)$, and anorthite Ca**Al** $(AlSi_2O_8)$, atomic isomorphism being evident.

If it be inquired what sort of structure underlies these formulas, then in the absence of X-ray interpretation of the plagioclases, some suggestion may perhaps be obtained by comparison with the already cited instance of isomorphism between $CaCO_3$ and $NaNO_3$. The X-ray study shows them to possess the structure: $\equiv Ca \equiv (C \equiv O_3) \equiv$ and $\equiv Na \equiv (N \equiv O_3) \equiv$, the atomic as well as the valence isomorphism being complete. Calcium and sodium have lost such valence-dissimilarity as they exhibited when in solution and both have attained a valence (or pseudo-valence) of 6. Carbon and nitrogen, in solution presumably 4 and 5 valent, respectively, both become primarily trivalent in the crystal. In so far as the metal is united to the non-metal thru oxygen, the oxygen atoms have here become likewise trivalent. In other words, the valence relations in the solution merely limit the types of compounds which can crystallize out—preventing the development of $CaNO_3$ or $NaCO_3$ for instance—but do not continue to hold once the solid form is attained. If it is remembered that the suggestion is purely hypothetical, the inquiry may be answered by stating that albite might be something like $\equiv Na \equiv (Al \equiv O_3) \equiv (Si_3O_5) \equiv$, and anorthite $\equiv Ca \equiv (Al \equiv O_3) \equiv (AlSi_2O_5) \equiv$.

Finally, it remains to be considered whether the atomic isomorphism viewpoint is capable of furnishing any adequate explanation of the failure of orthoclase or of carnegieite to show isomorphism with anorthite. The modern geometrical theories of crystal structure, which are being in every respect confirmed by X-ray study, imply that atomic isomorphism should be the rule whenever the atoms concerned are so nearly equal in volume as to fit into the same geometrical arrangement. The calculations from the X-ray measurements made by W. L. Bragg[18] show sodium to occupy normally a volume very slightly greater than calcium, nitrogen but little less than carbon, and silicon similarly little less than aluminium. The two instances of isomorphism which have been discussed here are thus in entire accordance with the atomic volume relations. On the other hand, potassium occupies a decidedly larger volume than sodium or calcium; so potassium nitrate can not be expected to be isomorphous with calcite, nor orthoclase with anorthite. In the case of carnegieite, there are two sodiums for every calcium of anorthite, and the still larger volume required by these two atoms should make isomorphism even less possible.

It should be noted that there is no intention of claiming that valence isomorphism never occurs; for if a compound is sufficiently complex to have gaps in its geometrical structure, then two atoms may readily replace one of their own size by expanding into these gaps. This is the relation which has long been known as mass-isomorphism. All that is held is that valence isomorphism is not applicable to the plagioclases.

The atomic isomorphism viewpoint, in connection with the geometrical theory of crystal structure, is thus entirely capable of accounting for all of the relations observed in the plagioclase feldspars.

SUMMARY.—In this paper it is shown that the structural formula viewpoint is incapable of accounting for the isomorphism of the plagioclases, that the arithmetical viewpoint mistakes a corollary for a cause, and that only the atomic isomorphism viewpoint really corresponds to the data. As sodium is indicated by X-ray measurement to occupy approximately the same volume as calcium, and aluminium as silicon, the two feldspars may well have identical geometrical structures; the valence relations in solution merely require the one replacement to be accompanied by the other, and

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[18] Phil. Mag., **40**, 169, 1920.

do not persist into the solid form of the compounds. Orthoclase and carnegieite can not be isomorphous with anorthite because the potassium atom of the one, and still more the two sodium atoms of the other, demand more space than displacement of the calcium can furnish. The simplest formulas adapted to bring out all the relations are: Albite, $\mathrm{Na}\mathbf{Al}(\mathrm{Si_3O_8})$; anorthite $\mathrm{Ca}\mathbf{Al}(\mathrm{AlSi_2O_8})$.

## AUGITE AND HORNBLENDE FROM KILIMANJARO

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In the present paper are described some crystals of augite and hornblende which were collected in 1920 by Mr. Scott, of the Universal Film Company, on "the southeast slope of Kilimanjaro." Dr. W. F. Foshag, of the U. S. National Museum, kindly gave them to us for study and we acknowledge with pleasure our indebtedness to him for the opportunity to add a little to our scanty knowledge of the mineralogy of East Africa.

Little is known in detail of the rocks of Kilimanjaro. According to Hyland,[1] who studied a collection of rocks made by Mayer in 1887, there occur basalt obsidian, limburgite, nephelite basalt, feldspar basalt, tephrite, nephelite basanite with "rhomb" feldspars, and leucite basanite (the first leucite rock to be described from Africa). According to Meyer, in 1900, as cited by Reed,[2] the lavas are chiefly leucitic; while Jaeger[2] reports rhomb prophyry as most abundant, with trachyandesite, trachydolerite, and recent phonolite. There can be no doubt that the lavas of Kilimanjaro in general are dominantly sodic and not very high in silica; and that they resemble those of Kenya and the other volcanoes of the Ethiopian Rift Valley, as described by Prior[3] and others.

### Augite

The crystals of augite were evidently found loose in ash, but there is no information as to the kind of lava from which they come. They differ in some respects from those described by Becker,[4] which were also loose crystals. The form and size of our augite crystals are the usual form and size for such augites. They are about 1 cm. long, and of the usual habit; bounded by the planes $a(100)$, $b(010)$, $m(110)$, and $s(\bar{1}11)$, with slight tabular development parallel to (100). They are jet black, with bright faces, and are wholly free from attached scoria. The density was not determined.

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[1] Hyland, J. S., *Tsch. Min. Pet. Mitth.*, **10**, 203, 1888.

[2] Reed, F. R. C., Geology of the British Empire, 1921, p. 75.

[3] Prior, G. T., *Min. Mag.*, **13**, 228, 1903.

[4] G. Becker, ref. in *Zeits. Kryst.*, **38**, 317, 1904.

There is a distinct zonal structure, with differences of 2° in extinction angle and of 0.025 in the refractive index $\beta$. The lowest value of $\alpha$ found was 1.684, and the highest value of $\gamma$ was 1.737; from which are estimated the average values: $\alpha = 1.69+$, $\beta = 1.70+$, and $\gamma = 1.72+$; $2V =$ about 60°; $\gamma_r \wedge c = 43° - 45°$, and $\gamma_v \wedge c = 45° - 47°$. No axial dispersion was visible about the axis, A, therefore $2V_r$ must be about 4° greater than $2V_v$. For comparison with these figures the analyzed samples of several other augites were examined to determine the character of the dispersion, the variations of the refractive index $\beta$, and other optical properties not already recorded. These data and some others taken from previous descriptions are given in Table 1.

### TABLE 1

| | | | DISPERSION | |
|---|---|---|---|---|
| | $\gamma^r \wedge c$ | | Axes | Bisectrices |
| Scano[a] | 44°–46° | 1.69–1.71 | $2V_r > 2V_v$ | $\gamma_r \wedge c < \gamma_v \wedge c$ |
| Stromboli (1914)[b] | 43°–45° | 1.70–1.71 | | |
| Vesuvius (1914)[c] | 46°–47° | 1.70–1.71 | | |
| Etna (1669)[c] | 48°–49° | 1.71–1.71+ | | |
| Haleakala[d] | 47°–48° | 1.70+–1.71 | | |
| Kilimanjaro | 43°–45° | 1.70–1.72 | | |

[a] Washington, H. S., *Jour. Geol.*, 22, 747, 1914.

[b] Kozu and Washington, *Amer. Jour. Sci.*, 45, 463, 1918.

[c] Washington and Merwin, *Amer. Jour. Sci.*, 1, 20, 1921.

[d] Washington and Merwin, *Amer. Jour. Sci.*, 3, 117, 1922.

A chemical analysis was made of the powder freed from the small amount of inclusions by repeated treatment with a powerful magnet. The results are given in Table 2, with an analysis of an augite from Kilimanjaro by Becker. Analyses of similar augites will be found in the papers cited above in connection with the optical characters.

The material of No. 1 was dried at 110°; the manganese was determined colorimetrically. The analysis by Becker was carried out by a peculiar method in which silica was recovered from a precipitate by ammonia, ignited and fused with potassium bisulphate. As silica is notably soluble in this melted salt, his silica is

TABLE 2

ANALYSES OF KILIMANJARO AUGITE

| | 1 | 2 |
|---|---|---|
| $SiO_2$ | 48.16 | 44.89 |
| $TiO_2$ | 0.59 | 2.39 |
| $Al_2O_3$ | 8.45 | 3.93 |
| $Fe_2O_3$ | 2.86 | 2.72 |
| FeO | 3.55 | 10.54 |
| MnO | 0.10 | n.d. |
| MgO | 14.23 | 12.79 |
| CaO | 21.69 | 22.13 |
| $Na_2O$ | 0.91 | n.d. |
| $K_2O$ | 0.10 | n.d. |
| $H_2O+$ | 0.15 | 0.11 |
| | 100.79 | 99.50 |

1. Augite from Southeast slope of Kilimanjaro. Washington analyst.
2. Augite from Kilimanjaro. G. Becker analyst. Ref. in *Zeit. Kryst.*, **38**, 317, 1904.

certainly low. Titanium was determined by the old and unreliable method of prolonged boiling with $SO_2$, which leads to serious plus or minus errors; the $TiO_2$ in No. 2 is, therefore, untrustworthy and presumably too high. The alkalies were not determined in Becker's analysis, which has little value, and which certainly does not justify the elaborate calculations of the molecular composition which he deduces from it.

The analysis of our augite is much like those of other augite crystals found loose at different volcanoes, some of which have been referred to above in discussing the optical characters. It is noteworthy that this chemical and optical resemblance holds despite very marked differences in the chemical characters of the magma or rocks from which the pyroxene is derived. Thus, the augite from Kilimanjaro is associated with decidedly sodic magma, as is that of Scano; those from Etna, Stromboli, and Haleakala with rather ordinary basaltic magmas; and that of Vesuvius with potassic leucite tephrite. It appears, also, that these augites differ, especially in their high content of diopside and low content of hedenbergite, from the common augite of the plateau basalts, such as those of the Deccan in India and the flows of the Columbia and Snake Rivers. These general relations will be discussed elsewhere.

## HORNBLENDE

Only four crystals were available. They were about one centimeter long, stoutly prismatic, and of a usual habit; bounded by the planes *b*(010), *m*(110), *p*($\bar{1}$01), and *r*(011).[5] They were velvet black, with smooth, lustrous faces. The specific gravity was found to be 3.213 at 30°, but this is probably too low because of the inclusions of glass.

Optically they are very homogeneous, with variations of about ±0.002 from the following refractive indices: $\alpha = 1.675$, $\beta = 1.691$, $\gamma = 1.701$. The extinction angle $\gamma \wedge c = 11°$ for violet and 12.5° for red. There is a scarcely noticeable pleochroism. For comparison with chemically similar hornblendes, there are given Ford's[6] determinations on amphiboles analyzed by Stanley from Monte Somma and from Bilin, Bohemia. For the Monte Somma hornblende, the mean index $= 1.68$, extinction angle not given; for the Bilin hornblende, the mean index $= 1.692$, extinction angle $\gamma \wedge c = 1°12'$ in the acute angle $\beta$.

The chemical analysis of the Kilimanjaro hornblende, after removal of the glassy inclusions by treatment with the magnet, gave the results of Table 3, two of Stanley's analyses being given for comparison.

TABLE 3

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 41.97 | 39.48 | 39.95 |
| $Al_2O_3$ | 12.59 | 12.99 | 17.58 |
| $Fe_2O_3$ | 4.69 | 7.25 | 7.25 |
| FeO | 5.80 | 10.73 | 2.18 |
| MgO | 14.20 | 11.47 | 14.15 |
| CaO | 11.99 | 12.01 | 11.96 |
| $Na_2O$ | 3.17 | 1.70 | 3.16 |
| $K_2O$ | 1.63 | 2.39 | 1.98 |
| $H_2O+$ | 0.26 | 0.76 | 0.41 |
| $H_2O-$ | .... | 0.12 | 0.13 |
| $TiO_2$ | 4.20 | 0.30 | 1.68 |
| F | n.d. | 0.05 | 0.03 |
| MnO | n.d. | 1.00 | trace |
| | 100.50 | 100.25 | 100.46 |
| Sp. Gr. | | 3.283 | 3.226 |

1. Hornblende. Southeast slope of Kilimanjaro. Washington analyst.

2. Hornblende. Monte Somma, Italy. Stanley, analyst. Penfield and Stanley, *Amer. Jour. Sci.*, **23**, 41, 1907.

3. Hornblende. Bilin, Bohemia. Stanley analyst. Penfield and Stanley, *op. cit.*, p. 47.

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[5] Cf. Goldschmidt, Atlas der Krystallformen, **1**, Tafel 11, Figs. 6 and 7.

[6] W. E. Ford, *Am. J. Sci.*, **37**, 181 and 188, 1914.

In the analysis of the Kilimanjaro hornblende the small amount of material available precluded the determination of manganese and fluorine; but it is reasonable to suppose that the percentages of both are very low. The analysis is remarkable for the rather high percentages of soda and (especially) potash, and also for the rather high titanium, which was determined colorimetrically. The material was dried at 110°.

Stanley's analysis of the Monte Somma hornblende resembles that of Kilimanjaro in most respects, but ferrous oxide is higher, as is ferric oxide, and magnesia is lower, while soda is lower and potash higher. The extraordinarily high percentage of manganese oxide in Stanley's analysis is almost certainly too high; and the rocks and minerals of Vesuvius are not notably high in manganese, rather the contrary. The Bilin hornblende is similar in many of its chemical features, but the alumina is suspiciously high, the iron oxides are in inverse relation to those in the Kilimanjaro and other similar, well-analyzed hornblendes, while magnesia and lime, soda and potash are much as in the African hornblende. In both of the hornblendes analyzed by Stanley titanium is much lower than in that from Kilimanjaro, and the amount of fluorine is insignificant.

Penfield and Stanley discuss the structural composition of the hornblendes whose analyses are given in Table 3, along with those of others, but it is not necessary to do this here with that from Kilimanjaro. The three hornblendes come from volcanoes whose lavas are decidedly alkalic (in the case of Monte Somma potassic), and the high soda is thus interesting and significant of some relation between the magma and the composition of the hornblende of lavas, as contrasted with that of the augite, from the same volcano, as is illustrated by the analyses of augite and hornblende from Kilimanjaro and Vesuvius (Somma) given here. The point seems to be worthy of further study, when more appropriate analyses of suitable occurrences are available.

## BOOK REVIEW

LEHRBUCH DER MINERALOGIE. PAUL NIGGLI. *Berlin W 35:* Gebrüder Borntraeger. Large 8vo., 694 pages. 1920.

This constitutes another book which has a somewhat misleading title. We usually think of a text-book of mineralogy as a book containing more or less introductory or explanatory matter and then descriptions of minerals; here the "introduction" makes up most of the book, and minerals as such are not described at all. A more accurate title would be "Modern methods of studying, interpreting, and understanding minerals."

In the 150 pages devoted to crystallography we do not find crystals taken up system by system or class by class, as in ordinary books; instead there is an elaborate discussion of arrangement of points in space, of symmetry-operations and their results, and of crystal forms in the order of their number of faces and symmetry features. There is a well-illustrated discussion of twinning and its structural significance; altho crystal measurement and calculation are dismissed rather too briefly. The physical properties of crystals are then considered, being discussed thruout from the structural viewpoint. The chapter on optics is treated in a more usual manner, and curiously enough only rock-making minerals are given as illustrations. Structure determination by X-rays is of course fully described, while radioactivity of minerals is treated briefly.

The section headed "Kristallchemie" is especially interesting. In it polymorphism, isomorphism, etc., are discussed from the most up-to-date viewpoints. Then there is an illuminating treatment of the relation of chemical composition to crystal form. Silicate formulas are written according to a modified Werner coördination plan, to which there is no objection except that unnecessarily complicated ones are used. The chapter on crystal habit and its causes is also good, and the section ends with a useful collection of data on colloid minerals.

Nearly 200 pages are then devoted the subject of origin and occurrence of minerals, with full discussions of pseudomorphs, magmatic phenomena and minerals, weathering and metamorphism and their mineral associations. Graphic methods are freely used in bringing out the relations, and the modern physical chemical viewpoint is held thruout. Finally there is a 6-page list of books on the various subdivisions of mineralogy, and a 23-page mineral list, in which name and formula are given for all minerals which the author has been able to locate, species being emphasized by bold-face type, and varieties or synonyms clearly designated.

The frequent criticism of text-books, that they are necessarily a generation behind the times, is distinctly inapplicable to this up-to-the-minute book. Except in so far as the experimental work of the Geophysical Laboratory is concerned, the modern trend of mineralogical thought in America is, to be sure, inadequately pictured in it. But every American mineralogist must turn to it to find out what has been done in central Europe during the past ten years; and no one writing a mineralogical article which is other than merely descriptive can afford not to refer to it.

W.

## PROCEEDINGS OF SOCIETIES

### NEW YORK MINERALOGICAL CLUB

The annual meeting of the New York Mineralogical Club was held in the American Museum of Natural History on the evening of Wednesday, April 12th at 8:00 P. M.

The President, Dr. George F. Kunz, presided and there was an attendance of 28 members. Mr. Whitlock reported for the Committee on proposed Sunday field trips as follows: Peekskill (Emery Mine), Davenport Neck, New Rochelle, Portchester, Sing Sing (Prison Quarry), Great Notch, Englewood (Printin Quarry), South River, N. J., Plainfield, N. J., Chimney Rocks, Sommerville, N. J., Hastingson-Hudson, Marble Hill, Jerome Park Reservoir, Bedford, Valhalla, Brown's Quarry (Carmel), Upper Montclair and Arlington, N. J. Mr. Hoadley on behalf of the Committee on the preparation of a map of localities within a radius of 25 miles of New York, submitted a map with the localities indicated by stars. After discussion the matter was laid on the table. Mr. Broadwell reported for the Committee on Badges and submitted a design adopted by the Newark Mineralogical Society.

The Committee on Membership reported favorably on the following names: Mr. Edwin F. Gross, 1169 East 17th Street, Brooklyn; Mr. E. Victor Collins, 125 East 28 Street, New York; Mr. Herbert L. Thowless, 765 Broad Street, Newark. The name of Miss Florence Miller of 606 West 115th Street, New York, was submitted to the Committee on Membership by Mr. Westervelt.

The Treasurer submitted the annual report showing a balance of \$478.73. It was moved by the President that the income from life memberships alone be available for the Treasurer to draw against. Motion carried.

The Committee on Nomination of Officers for the Year 1922–23 recommended the continuance of the present officers of the Club. It was moved that Mr. Ashby cast a ballot for the following officers:

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| For President | George F. Kunz |
| For Vice President | George E. Ashby |
| For Corresponding Secretary | Wallace G. Levison |
| For Recording Secretary | Herbert P. Whitlock |
| For Treasurer | Gilman S. Stanton |

The motion was carried and the above officers declared elected.

Captain Miller moved that a Lecture Committee be appointed by the Chair to arrange for speakers for the coming year. On the motion being carried the Chair appointed the following Committee: President, Recording Secretary (ex officio), Messrs. Manchester, Wintringham, R. M. Allen, Lee, Ashby, and F. I. Allen.

Dr. Kunz exhibited some photographs of notable specimens of minerals from Minas Geraes, Brazil. He then introduced the speaker of the evening, Mr. Samuel G. Gordon of the Philadelphia Academy of Science, who gave a very interesting address on "MINERAL COLLECTING IN THE ANDES." Mr. Gordon described a recent visit to the mineral localities of Bolivia, Peru and Chile, and illustrated his talk by many beautiful lantern slides of Andes scenery, and also of some of the mineral specimens collected for the Philadelphia Academy. At the close of his address a vote of thanks was tendered him for his very instructive and original paper.

HERBERT P. WHITLOCK, *Recording Secretary*

## PHILADELPHIA MINERALOGICAL SOCIETY

*Academy of Natural Sciences, May 11, 1922*

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Trudell, in the chair. Nineteen members and one visitor were present.

Mr. J. C. Boyle addressed the society on "THE ZEOLITES." The physical and chemical characteristics of the group were described, followed by a discussion of their mode of origin and occurrence. The lecture was illustrated with specimens and lantern slides.

Mr. Gordon presented two short papers on "NOTES ON WILLEMITE, CELESTITE, AND CALCITE FROM FRANKLIN, N. J.," and "THE CRYSTALLOGRAPHY OF GLAUCOCHROITE." Specimens were exhibited.

Messrs. Vaux and Wills described two trips to the French Creek mines. Mr. Biernbaum described a trip to the Poorhouse quarry, and the Unionville district.

SAMUEL G. GORDON, *Secretary*

## NEW SPECIES

### FAMILY: SULFATES, CHROMATES, MOLYBDATES, TUNGSTATES, AND URANATES

### SUBFAMILY: URANATES. DIVISION: $RO:UO_3:H_2O=2:5:X$

### Curite

ALFRED SCHOEP: La curite, nouveau minéral radioactif. (Curite, a new radioactive mineral.) *Compt. rend.*, **173**, (23), 1186–1187, 1921.

NAME: Stated to be in honor of Pierre *Curie.*

CHEMICAL PROPERTIES: *Formula:* $2PbO.5UO_3.4H_2O$, or $Pb_2(4H_2O)\ U_5O_{17}$. Mean of 3 analyses gave: $PbO$ 21.32, $UO_3$ 74.22, $H_2O$ 4.00, $Fe_2O_3$ 0.17, sum 99.71. Soluble in cold acids, becomes brown and yields water in closed tube, and shows strong radioactivity.

CRYSTALLOGRAPHIC AND OPTICAL PROPERTIES: Shows only needles too minute to measure, with parallel extinction, + elongation and $n > 1.74$.

PHYSICAL PROPERTIES: Color reddish brown, by transmitted light deep yellow. Streak, orange. $H=4-5$. Sp. gr. $=7.192$. Form ranging from crypto-crystalline to massive; also acicular crystals.

OCCURRENCE: Found at Kasolo, Katanga, Belgian Congo, associated with torbernite and an unidentified mineral.

DISCUSSION: In spite of the incomplete crystallographic-optical data, this may be accepted as a valid new species. It is, however, related to the mixture known as gummite, which may contain curite together with other uranates.

E. T. W.

### FAMILY: SILICATES. DIVISION: $R'':R'''''':R'''':H_2O=1:1:1:1$.

### Kasolite

ALFRED SCHOEP: Sur la kasolite, nouveau minéral radioactif. (On kasolite, a new radioactive mineral.) *Compt. rend.*, **173** (26), 1476–1477, 1921.

NAME: From the locality, *Kasolo*, Katanga, Belgian Congo.

CHEMICAL PROPERTIES: *Formula:* $PbO:UO_3:SiO_2:H_2O$ or $Pb(UO_2)[H_2O](SiO_4)$. [Author gives $1\text{-}\frac{1}{3}$ $H_2O$]. Theory: $PbO$ 38.0, $UO_3$ 48.7, $SiO_2$ 10.2, $H_2O$ 3.1%. Three analyses were made, on crystallized, crystalline-granular, and compact material, respectively, all giving about the same values, with the ranges: $SiO_2$ 9.00–9.42, $PbO$ 32.16–36.20, $UO_3$ 48.36–49.28, $H_2O$ 3.28–3.77, $Fe_2O_3$ 0.40–0.58, $CaO$ 0.06, $MgO$ 0.03, $CO_2$ 0.53–0.85%. Optical examination showed the samples analyzed to be homogeneous except for the presence of a little dolomite, which is evidently the source of the several last constituents. Soluble in acids with gelatinization. In closed tube gives $H_2O$; on charcoal B.B. gives reactions for Pb.

Radioactivity like that of curite (another new mineral from the same locality, see abstract above).

CRYSTALLOGRAPHIC AND OPTICAL PROPERTIES: System monoclinic; habit prismatic; crystals not exceeding 2x1 mm. Plane of optic axes perpendicular to symmetry plane; acute bisectrix making about 90° with a cleavage plane. Refractive indices high.

PHYSICAL PROPERTIES: Color yellow, ocher-like to brown. Luster resinous to greasy. Translucent to opaque from incipient alteration. Structure ranging from crystallized, in radiating needles, to crystalline granular and compact-massive. Sp. gr. 5.962. H. 4–5.

OCCURRENCE: Found associated with curite and torbernite at Kasolo.

DISCUSSION: The distinctness of this species is apparent, altho the data given are not as complete as might be desired; however, the author promises another paper.

E. T. W.

## FAMILY: BORATES, ALUMINATES, ETC.; SUBFAMILY: BORATES. DIVISION: $R'':R''':H_2O=2:1:1$

### Camsellite

H. V. ELLSWORTH AND EUG. POITEVIN: Camsellite, a new borate mineral from British Columbia, Canada. *Trans. Roy. Soc. Canada*, (IV), series 111, **15**, 1–8, 1921.

NAME: In honor of Chas. Camsell, Deputy Minister, Canada, Dept. of Mines.

CHEMICAL PROPERTIES: *Formula:* $2\ MgO.\ B_2O_3.\ H_2O$, or $HMg(BO_3)$. Analysis gave, $SiO_2$ 7.65, $Fe_2O_3$ 0.86, FeO 0.95, MnO 0.85, $Al_2O_3$ 0.26, CaO 3.69, MgO 41.72, $B_2O_3$ 29.07, $Na_2O+K_2O$ 0.03, NiO trace, $H_2O+110°$ 9.88, $H_2O-0.52$, $CO_2$ $5.64=100.12$. After deducting analyzed chrysotile and dolomite the recalculated analysis gave: MgO 45.24, $Fe_2O_3$ 0.85, FeO 1.28, MnO 1.09, $Al_2O_3$ 0.29, $B_2O_3$ 40.40, $H_2O+110°$ 10.55, $H_2O-110°$ 0.26, $Na_2O+K_2O$ $0.04=100$. Water is chemically combined, total loss including possibly some $CO_2$ up to $550°=2.95\%$. Camsellite appears to be of sufficient stability to admit of its having been produced at the range of temperature ascribed to pneumatolytic action. Before the blow-pipe, fuses readily and quietly to opaque brownish glass imparting green color to the flame. Soluble in HCl, $H_2SO_4$, and $HNO_3$.

CRYSTALLOGRAPHIC AND OPTICAL PROPERTIES: System probably orthorhombic. Extinction parallel, elongation negative, pleochroism weak. $\alpha=1.575\pm0.005$; $\gamma=1.649\pm0.005$; birefringence very strong, $\gamma-\alpha=0.074$.

PHYSICAL PROPERTIES: Color white. Form fibrous, asbestos-like in appearance. Hardness less than 3.

OCCURRENCE: Intimately associated with chrysotile and dolomite forming sheared veins in serpentine from near Douglas Lake, British Columbia.

DISCUSSION: Camsellite is related to sussexite, which has the same general formula, but in which manganous oxide is much in excess of magnesia.

E. POITEVIN

## NOTES AND NEWS

In a review of "The microscopic determination of the non-opaque minerals" by E. S. Larsen (*Am. Min.*, 7 (4), 70, 1922), the undersigned paraphrased statements in that work to the effect that 30 rare minerals were not included because not represented in available collections. Dr. Larsen now informs me that he did not intend to imply that these minerals were entirely unrepresented; he may have missed one or two, but in most of the cases in question removal of material for optical study would have seriously damaged valuable specimens, and they were accordingly omitted. Actually, 24 out of the 30 are included in the collection of Colonel Washington A. Roebling, so that this collection is even more complete than implied in the review.

E. T. W.

At the annual dinner of the National Academy of Science, the J. Lawrence Smith medal was bestowed upon Dr. George P. Merrill, Curator of geology at the United States National Museum. This gold medal was awarded in recognition of his investigations of meteoric bodies. At the same meeting Dr. Merrill was elected a member of the Academy.

At the meeting of the American Philosophical Society, held in Philadelphia, Dr. Henry S. Washington was elected a member of that Society.

A note in "Science" (May 5, 1922, p. 479) calls attention to a possible cause of the red color in solar salt and brine. Recent investigations tend to indicate that the color is due to micro-organisms that thrive in a media containing not less than 15% of salt by weight, and one in which the most favorable temperature is between 50° and 60° C.

From the fund collected by the women of America to present a gram of radium to Mme. Curie, there remains, after about $110,000 had been paid for the radium, a surplus of about $50,000, the annual income from which will be given to Mme. Curie.

The National Academy of Science has voted a grant of $500 (J. Lawrence Smith Fund) to Dr. George Perkins Merrill, of the U. S. National Museum for further investigations of meteorites.

We are pleased to report that Mr. John A. Roebling has been appointed a Regent of the Smithsonian Institution. He is the son of Colonel Washington A. Roebling, whose mineral collection has often been mentioned in this JOURNAL.

At the last annual meeting of the American Academy of Arts and Sciences, Professor Austin Flint Rogers, professor of Mineralogy at Stanford University and one of the editors of THE AMERICAN MINERALOGIST, was elected fellow of the Society.

Professor Charles Hyde Warren, professor of mineralogy at the Massachusetts Institute of Technology, has recently been elected Dean of the Sheffield Scientific School, in succession to Director Russell H. Chittenden.

Dr. Elwood S. Moore, Dean of the School of Mines of the Pennsylvania State College, has resigned to take charge of the work in economic geology at the University of Toronto.

On June 7th, 1922, George Washington University conferred on Oliver Bowles, mineral technologist of the Bureau of Mines, the degree of Doctor of Philosophy.